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Co-constructing an agent-based model to mediate land use conflict between herders and foresters in northern Thailand

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Abstract

Landscape dynamics are driven by complex interactions among ecological, social, economic, and policy factors. In conservation areas, these factors are usually related to an increasing number of diverse land resource managers and users. Land use conflicts occur frequently because they have different interest, objectives and perceptions of landscape resources and their use. Sharing these different, but all legitimate, perceptions of the landscape and its use among concerned stakeholders is a pre-requisite for better collective land management, particularly in conservation areas. This research is using the integrative companion modeling approach to co-construct an agent-based model representing the dynamic interactions between vegetation dynamics, reforestation efforts, and livestock grazing in the upper watershed of Nan province, northern Thailand. The paper focuses on the participatory modeling process implemented with local stakeholders at this site. Three main investigation tools were used to exchange and gather knowledge on ecological and human decision making processes: field surveys (land use history and analysis of vegetation dynamics at the landscape level), farmers' interviews (analysis of individual decision making and determining factors across different farm types), and institutional analysis in relation with changes in land use policy and related state interventions. This knowledge was first assembled in simple gaming exercises presented to local herders and foresters to further enrich and validate the researchers' understanding of key interactions regulating vegetation and land use dynamics. The outputs of these collaborative modeling activities were used to design a hybrid agent-based hybrid simulator blending a role-playing game and a computer program developed under the CORMAS platform. This simulation tool, representing the complex human and ecological interactions at the landscape level, allowed stakeholders to criticize and improve this comprehensive formalization of the landscape dynamics. It was also used to introduce simulation exercises with local stakeholders and to stimulate them to identify possible future land management scenarios mitigating the current conflict.

Key words: Companion Modeling, agent-based model, vegetation dynamics, livestock rearing, forest conservation, northern Thailand.

Introduction

Landscape dynamics of forest margins and origin of related land use conflict in northern Thailand

Landscape dynamics are driven by complex interactions among ecological, social, economic, and policy factors (Lambin *et al.* 2001). Integrative analysis has been proposed to investigate these complex interactions.(Lambin *et al.* 2003, Parker *et al.* 2003, Burgi *et al.* 2004). In the case of pioneer fronts along forest margins, the degradation and reduction of tree coverage due to the conversion to farmland has been studied in several countries (Walker *et al.* 2000, Gautam *et al.* 2003, Armenteras *et al.* 2006, Amsalu *et al.* 2007, Serra *et al.* 2008). In mountainous northern Thailand the rapid reduction of forest cover over the last four decades has been well-documented and linked to logging (Lakanavichian 2001), the construction of communication infrastructure and new human settlements, and the farming practices of some minority ethnic group (Fox *et al.* 1995, Ganjanapan and Kaosa-ard 1995, Kaosa-ard 2000). During 1960-2004, the northern forest cover decreased from 27.4 to 16.8 million ha (Royal Forest Department 2006). In this context, the importance of forest conservation in headwater areas is increasing and has led to new initiatives by different institutions since the 90s. While, more than in the past, current dynamics along the forest – farmland interface depend on the implementation of the government's conservation policies, they are still significantly affected by local renewable resource users' own strategies and practices, with both group having strongly different interests, perceptions and objectives in land management.

The Royal Thai Government (RTG) considers that forest cover needs to recover and therefore, new conservation areas have been recently established. During 1990-2004, the total area of national parks or forest parks and wildlife sanctuaries increased from 5.9 to 8.9 million ha and more of them have still to be officially declared (Royal Forest Department 2006). The RTG has classified watersheds into different categories and issued laws to regulate the type of human activities allowed for each of them. For example, Class 1A and 1B watershed are fully protected as headwater forest areas and no human activity is allowed in the absence of special permissions granted in some areas (Department of National Park Wildlife and Plant Conservation 2008).

At the same time, the gradual integration of highland farmers into the market economy during the last three decades led to the expansion of farmland on sloping land and a growing concern from the authorities for soil erosion risk (Turkelboom *et al.* 2008). For the last two decades, a substitution of soil erosion – prone annual crops by perennial plantations, especially orchards, has been encouraged. Between 1980 and 2006, the total area of farmland in the country increased from 19.0 to 20.8 million ha, but areas planted to orchards jumped from 1.8 to 4.6 million ha during the same period (Office of Agricultural Economics 2007). This commercialization of highland agriculture has led to extensive socio-economic differentiation among farming households, with the more resource-poor holdings still relying on public land (for traditional livestock raising) and forest resources (timber and non-timber forest products) for their economic survival. As a result, they are often blamed to be forest encroachers by officials and lowlanders (Roth 2004, Delang 2005) and such perceptions are frequently at the origin of land use conflicts between RTG forest conservation agencies and local resources users. But the RTG started to decentralize the local management of renewable resources in the mid-90s and, faced by stronger civil society movements, attempted to recognize local people rights in order to mitigate such conflicts.

Toward decentralized and participatory management of renewable resources

At the sub-district (*tambon*) level, the Tambon Administration Organization (TAO) system was first established in 1994 with a mandate to protect and manage local natural resources and TAOs have been receiving an increasing share of public funding in recent years to implement local projects. However, in most cases the level of participation by villagers is still limited to receiving information and consultation, while few projects involve local people in monitoring and evaluation activities (Neef 2005). For example, the establishment of several national parks involved local farmers in the co-delineation of the park boundary, but they did not have much opportunity to collaborate with government conservation agencies in setting up the natural resource management plan and monitoring resource state.

Contradiction between the national legal framework and local use and rights regarding the management of renewable resources in conservation areas

Following the establishment of a new conservation area, the national law is strictly enforced within its boundaries through the idea of 'no human interference' (Vandergeest 1996, Hares 2009). As a result, local people who have been depending on these land resources for a long time protest and the official agencies have to be more flexible in the implementation of the new rules to avoid violent conflicts. Recently, however, local forest managers can reach compromises with villagers regarding specific activities, for example gathering non-timber forest products (NTFPs) for self consumption could be allowed within a set of agreed upon rules on types of plants and animals covered by the agreement, limited periods and volumes for their collection, etc. But frequently these rules are set up by officials, without engaging any real dialogue with local villagers, and are difficult to enforce at a later stage because they usually do not meet their needs. Therefore, because more conservation areas are being planned, there is a urgent need to design and test truly inclusive and participatory approaches to promote a more adaptive management of renewable resources based on improved communication to exchange perceptions and knowledge, joint learning, and collective decision making leading to acceptable action plans to be monitored by the different types of resource users.

Study site in Nan province and choice of the Companion Modeling (ComMod) approach

Nan province, located in the eastern part of northern Thailand, has 7 national parks, 1 wildlife sanctuary and several. Therefore, the type of above-mentioned conflict over access to land resources is common in this relatively remote part of the kingdom partly populated by several non-Thai ethnic groups of highlanders such as the Hmong, Karen, Lue, H'tin, Lawa, etc. Recently, the economy of these highland villages has been affected by forest conservation and rehabilitation policies and the abrupt fluctuations of farm gate prices of their farm products, especially the horticultural ones.

The authors selected the Hmong village of Ban Doi Tiew located in Tha Wang Pha District, along the border of the new Nanthaburi National Park (NNP) and in the Nam Kang headwater research and development unit (NKU), to test the suitability of the collaborative Companion Modeling (ComMod) approach based on multi-agent systems (MAS) to mitigate a conflict over the access to grazing land between local livestock herders and forest conservation agencies. ComMod is a participatory modeling approach which typically pursues two objectives, to understand the complex social-ecological system, and to support negotiation and collective decision making process in the management of common resources (Bousquet and Trébuil 2005). Its principle seems to be in suitable with the above-mentioned objective of introducing truly inclusive and participatory approaches to promote a more adaptive management of renewable resources (see details of ComMod in next section). Moreover, this approach was previous used in different management contexts with other ethnic groups (Promburom 2004, Barnaud *et al.* 2007, Barnaud *et al.* 2008).

The objective of this article is to describe and assess the participatory modeling process used that led to the co-construction of an agent-based model (ABM) with concerned stakeholders to (i) represent the interactions between vegetation dynamics, reforestation efforts, and livestock grazing practices, and (ii) facilitate the communication among Hmong herders and RTG forest managers in this upper watershed of Nan province.

Following a presentation of the ComMod approach fundamental principles and key characteristics, more information on the land resource management context at the study site will be provided. The following part will describe the phases, procedures, and modeling tools of the overall ComMod process implemented so far. A step by step illustrated presentation and discussion of the results obtained so far will point to the strengths and weaknesses of the selected methodological approach. Finally, the next steps of this research and the corrective measure taken are discussed in conclusion.

Materials and methods

The Companion Modeling (ComMod) approach

Companion Modelling (ComMod)[1] belongs to a family of trans-disciplinary participatory modelling approaches. It main principles are to develop simulation models integrating various stakeholders' points of view and to facilitate dialogue, shared learning, and collective decision making (Barreteau 2003). ComMod emphasizes better understanding of interactions between ecological and socio-economic dynamics in a complex and uncertain system through iterative cycles alternating field observations and model implementations. Stakeholders' decision making processes are considered as important to understand such interactions. In ComMod, the researchers are considered as one type of stakeholders in the arena because they can influence other stakeholders' decisions since starting the research. All points of view on the problem to be examined are considered as *a priori* legitimate ones. There are four main iterative and evolving phases alternating laboratory and field to be implemented with the stakeholders: i) Diagnosis and problem identification, ii) Sharing, adjustment and improvement of knowledge and perceptions on the problem facilitated by gaming and simulations to achieve a shared representation of the problem at stake, iii) Collective debates to generate acceptable scenarios to be tested and agreed-upon indicators for their evaluation, and iv) Computer simulations to support the collective assessment of these scenarios and decision-making on further action to be taken (Bousquet and Trébuil 2005). In ComMod process, several complementary tools will be implemented, such as Multi-Agent Systems (MAS), Role-Playing Games (RPG), Geographic Information System (GIS), focused group debates, and in-depth interviews. They will be used to explore decision making processes related to land and resource use. A visual communication platform integrating various stakeholders' points of view based on different kind of knowledge (scientific and indigenous), and the contributions from different disciplines (social and ecological ones) will be constructed.

MAS emphasize on interactions between agents and the phenomenon of emergence from these interactions that makes it different from classical systems approaches (Ferber 1999). A multi-agent system comprises a set of computer processes taking place simultaneously, several agents living at the same time, sharing common resources and communicating with each other (Bousquet *et al.* 1999). Nowadays, among many modelling tools, MAS are increasingly used in the field of environmental and natural resource management (Trébuil *et al.* 2002, Barreteau *et al.* 2004, Bousquet and Le Page 2004). The RPG is another interactive and participatory tool which can be used in conjunction with MAS-based participatory simulations to produce a typology of management strategies, and to

[1] More information on ComMod is available at http://www.commod.org and http://www.ecole-commod.sc.chula.ac.th

facilitate learning and negotiation. It can also be used to understand the systems dynamics and generate information to design MAS models (Bousquet *et al.* 2002). In ComMod, RPGs are also used as a tool to facilitate the sharing of points of view, representations of the system to be managed, and of the problem to be examined among stakeholders. There are various ways of associating RPG and MAS models, but often the RPG is used to help the stakeholders understand what the computerized MAS model will be doing. The RPG can also be used in the social validation of the MAS model before to conduct participatory simulations to assess future scenarios identified by the people (Barreteau *et al.* 2001).

Study site

The elevation of Doi Tiew agro-ecosystem ranges from 900-1200 m amsl. This Hmong village has been farming in this area for more than 60 years. While current major crops grown are maize, upland rice, and litchi orchard, low external input cattle rearing is also practiced in both natural and farmland (fallows and orchards) areas. The land use conflict between Doi Tiew villagers and RTG forest management agencies finds its origin in the establishment of the NKU by the Royal Forestry Department (RFD) in 1990, followed by the preliminary delimitation of the extensive NNP in 1996. Figure 1 display change made in the NNP boundaries between 1996 and 2006, and shows its current less ambitious extent at the time of its official declaration following a decade of negotiated adjustments with local villagers.

Apart from these two RTG agencies, other forest management institutions located in the study area include the Sob Khun Royal Project (SKP) and the Sob Sai, Nam Haen, and Nam Ngao headwater management units. Their reforestation activities over recent years, combined with the attempt to enforce the law on national parks led to a sharp decrease in the amount of land available, approximately 3,000 ha, for cropping and particularly grazing activities while the village population is still increasing, 50 households in 1961 to 170 households (1,307 individuals) in 2007. As a result, the villagers' livelihoods have been profoundly transformed and social inequity among households increased rapidly. The former agricultural system based on annual crops and long fallows is not adapted to these new environmental conditions anymore and is giving way to a combination of more permanent cash cropping activities associated to various off-farm employment activities (Dumrongrojwatthana *et al.* forthcoming).

At the start of our research, there was no substantial dialogue between NKU foresters and NNP rangers and Doi Tiew villagers to defuse the growing tensions on access to land by identifying a common management plan acceptable to all concerned parties.

Methodological steps and associated tools

Initially, a preliminary diagnostic-analysis of the land use problem was varied out in 2007-2008 by using the following three main complementary investigation tools:

- Field survey and laboratory study using plot sampling and remote sensing techniques to understand and quantify the recent history of land use change and vegetation dynamics at landscape level in relation with the evolution of farming practices and the village environmental conditions (Trébuil 1988).
- In-depth individual interviews with stakeholders (approximately 70 individuals) to understand their respective objectives and strategies regarding the use of forest and land resources, as well as their decision making processes about land use. Based on this information, a farmer typology was built to show the relative importance of livestock rearing among different types of households and their associated land use strategies (Trébuil 1990, Valbuena *et al.* 2008).

- A stakeholder and institutional analysis (Grimble and Wellard 1997) to understand recent changes in land use policy and their relations with local state interventions, and the objectives and strategies of the RTG forest management institutions active in the study area.

Based on the knowledge provided by this comprehensive analysis of the context and issue to be examined, a preliminary model was conceptualized and a prototype ABM designed in the lab. The PARDI modeling tool was used to characterize the Problem, Actors, Resources, Dynamics, and Interactions to be represented in the individual-based model (Etienne *et al.* 2008). The construction of this initial conceptual model involved the preparation of several diagrams representing vegetation state transitions and human - resource interactions. Later on, these diagrams were used to code a first prototype ABM under the CORMAS (COmmon-pool Resources and Multi-Agent Systems) simulation platform (Bousquet *et al.* 1998, Le Page and Bommel 2005).

This phase was followed by sensitizing exercises with 2 key stakeholders, village herders and NKU foresters, because they have a clear conflict on land use for cattle grazing and reforestation. The other concerned stakeholders may be involved in the process if needed. The five village herders and four foresters were invited to the sensitizing exercises on 4-5 September 2008 during which a first version of the vegetation state transition diagram was submitted. They were selected based on their contrasted perceptions on the problem at stake and because they did not hold any discussion on this issue before. Both sides, foresters and herders, had a chance to express the reasons behind their perceptions of the situation to be improved and to agree upon a common vegetation state transition diagram from each side. This outcome was used by the research team to design suitable gaming and simulation tools to support the sharing of these two different points of view.

A participatory gaming and simulation field workshop was held during 22-26 September 2008 and is presented in table 1. Two days of gaming and simulation sessions where implemented, first with the herders only at their village school, and then with the NKU foresters as well at the district office on the next day. They were followed by individual interviews of the participants to gather more information on their assessment of the tools used in the proceedings, their relationship with actual circumstances, the players' own behavior and decisions made during the sessions, as well as their recommendations regarding the desirable contents and format of the next steps of the ComMod process.

A few weeks later, a poster displaying the activities and main results of this two-day was presented during a whole village meeting to provide feedback to non-players and stimulate further exchanges on the problem under study. The day after, it was also shown to the SKP and Department of Livestock Development (DLD) officials at the District level.

The key successive phases of this first sequence of the ComMod process carried out at Doi Tiew site is summarized in Figure 2.

Results

Characterization of the resource management problem and social-ecological context

<u>The herders and foresters perceptions of the problem were made explicit</u>

The initial diagnostic-analysis and the following sensitizing exercises conducted with the stakeholders led to clear expressions of their differences regarding the influence of cattle grazing on vegetation dynamics in reforestation areas: while farmers insist that cattle grazing can accelerate forest regeneration by reducing forest fire risk in young tree plantations, foresters think that livestock rearing damage seedlings and saplings by tramping and browsing, delay forest succession, and cause human-made forest fire in the dry season. These activities also confirmed the lack of communication between government agencies and villagers and the importance of building a shared representation of these agro-ecological interactions as a first step toward improved dialogue between the two parties.

A first conceptual model of vegetation dynamics influenced by human activities

The plant resources to be managed and their dynamics under the influence of reforestation, cropping and animal rearing (grazing pressure) human activities, including forest fire, were characterized and their relationships displayed in the first vegetation state transition diagram shown in figure 3 which summarized the research team understanding of land use and land cover change caused by different factors at this early stage of the collaborative modeling process.

An extensive socio-economic heterogeneity among herders

Based on the characterization of the amount of productive resources available and their related choice of cattle rearing and cropping systems practices, four main types of farmers were identified in Doi Tiew village. Figure 4 displays differences among them in the composition of household incomes and the relative importance of livestock in farm assets. Type A farmers who never raised livestock, or did not raise any cattle for many years, generate the main share of their income from off-farm activities such as wage employment or petty trade. Type B are resource-poor farmers growing crops on small holdings (usually less than 1.6 ha) and managing a herd of about 2-15 heads/household which is grazing mostly in forest and reforestation areas and is a significant source of income. Type C farmers receive the main share of their income from sales of crops grown on 1.6-3.2 ha and/or daily wages, and cattle rearing (herd size of 2-25 heads/household) in forest or reforestation areas and fallows is a secondary source of cash. With a herd size higher than 40 heads/household, cattle rearing, mainly in forest and reforestation areas due to the large number of animals, is a key economic activity on Type D farms. The sales of cattle is a main source of income as well as crop products harvested on usually more than 3.2 ha per holding. The ratio of type A, B, C, and D is approximately 1, 9, 4, and 1. This extensive differentiation among local farm types needs to be taken into account in the design of collaborative modeling activities and tools.

Relative importance and influence on the resource management problem of direct or indirect actors and institutions in the stakeholders' arena

The various direct and indirect (those who can influence the behavior of direct actors) stakeholders are plotted on Figure 5 according to the relative importance of the problem at stake for each of them and their level of influence on the outcome of the issue being examined. For example, type A farmer, the importance of cattle problem is not too high because they have no cattle currently. Type B farmer usually has low power compared to type C and D who are working closely with government agencies as a village headman or village committees. The local government agency such as NKU is considered that the cattle raising is an importance problem because it deals with sapling and seedling destruction. The NKU has authority to solve the problem by law implementation but lesser authority than NNP. Only a selection of the direct actors (the NKU and type B, C, and D farmers) for whom the cattle grazing and forest regeneration problem is important took part in the first set of collaborative modeling activities reported here.

The interactions among these key direct actors and the resources they manage are presented as a UML (Unified Modeling Language) class diagram in Figure 6. This conceptual diagram was used to build the first prototype of a computer ABM under the CORMAS simulation platform. This because the preliminary activities implemented with the farmers and foresters showed that their time available to join in collaborative modeling activities is limited. Therefore, the research team decided to design a computer-assisted role-playing game (C-RPG) as the main tool to be used in the subsequent participatory gaming and simulation field workshops. Because of the complexity of the ecological dynamics (i.e. succession of vegetation states) to be taken into account, the choice was made to build such a hybrid simulator in which the computer will be used to update vegetation states instead of series of time-consuming players' decisions that would have slowed the RPG too much.

Description of the prototype agent-based model

Model description was described based on the "Overview-Design concepts-Details (ODD)" proposed by a group of modelers as a standard protocol (Grimm *et al.* 2006). First, we start with the model 'overview' to give the idea of purpose, variables, scale, process overview and scheduling, then followed by the 'design concepts' to provide a common framework for designing and finished by 'details' section providing initialization and scenarios to be explored through the model.

Overview: This model was used for i) to improve the researchers understanding on vegetation dynamics in relation to cattle management and reforestation effort, and ii) to facilitate the communication among Hmong herders and RTG forest managers through different scenarios exploration.

The model static structure was represented by UML (Unified Modeling Language) class diagram (Figure 6) comprising of different entities (agents/resources), attributes and interactions. Land unit entity has 3 attributes; type, age and grazing level. Type comprised of 10 vegetation states evolving by rule-based (see the vegetation state diagram). Age refers to the age of each vegetation state and it was used for updating vegetation state from one to the next. Grazing level was identified into 3 levels: no grazing, low (cattle density is equal to or lower than 2.4 head/unit area), high (cattle density is higher than 1.4 head/land unit). Aggregate of land units are "Paddock" or "Reforestation" entities depending on herders' or foresters' decisions on land use, respectively. Each paddock contains total forage value for updating cattle status. Farmers entity has 3 attributes; identification, cattle, and paddock. Forester entity has a plots size attribute. In this combination model, real agents (3 types of farmers and NKU foresters were make decisions. This allows researchers to obtain diverse decisions and strategies for further building autonomous agent model. Cattle status can change over time step depended on total forage and grazing level in paddock. Aggregate of cattle is herd entity which containing 3 variables; numbers of cattle, new born rate, and death and losses rate. This makes dynamics of the model.

For the spatial interface of the model, simple spatial grids representing heterogeneity of landscape was built with total of 154 cells (11 column x 15 rows). Ten vegetation states and one river were distributed in the spatial interface (Figure 7).

The model proceeds in annual time steps. Within each year or time step, 7 phases were processed in the following order: foresters start reforestation, herders decide and locate herd in preferred paddocks size, update cattle status, update newborn, update death and loss, update herd size, and finished by update vegetation age and type. Simulation run was decided for 5 years to see evolution of vegetation states. This model was conducted with real players (agents), therefore, some phases were computed and some phases were decided by players (see model UML activity diagram in figure 8).

Design concepts: The concepts underlying the model's design were;

- *Collectives*: The model allowed player discuss to find the collective management strategies. For example, herders can pool cattle together in single large paddock.
- *Adaptation*: The discussion and negotiation during each time step allowed players to adapt their strategies to better manage cattle and forest resources.
- *Interaction*: Players managing the same landscape have to interact to meet good outcome. Among herders, they have to discuss and negotiate the paddock area and

location to avoid the land use conflict. Between herders and foresters, due to the different objective of land use, they have to negotiate to share the land resource.

- *Observation*: Indicators (figures showing evolution of landscape, individual herd size, and cattle status) were used to observe the result of simulation in each scenario.

As this model was used with real players, these concepts are related together. The time allocation in the real gaming and simulation session was designed to provide collective discussion among players to deliberate and adapt their decision making.

Details: Model initialization and scenarios to be explored were;

Initial spatial interface was simplified from the 2003 classified satellite image to present the forest-farmland interface (Figure 7). Ten vegetation states were distributed in the 154 cells of the landscape. Each cell referred to an area of 20 rai (3.2 ha) in reality. Therefore, 2,800 rai (448 ha) of vegetation cover are available for reforestation and cattle grazing. Moreover, the spatial interface was designed symmetry for further comparison of decisions and management strategies between 2 groups of herders.

In each time step of the model, decisions from players including reforestation plots, paddock, and herd size, were put to computer. There were 2 parts of model computing, computer and human (research assistants). Based on field information, the extensive cattle raising in this highland area has specific cattle biology. To simplify the model, simple rules were used. Update cattle status: The numbers of "*Imperata fallow*", "*Thysanolaena and Imperata fallow*", and "*Chromolaena and Imperata fallow*" vegetation states in each paddock were used to calculate cattle status each time step. Cattle status is "fat", if paddock is larger than 10 cells (land unit) and consists of 5-6 cells of those vegetation states, or paddock is smaller or equal to 10 cells and consists of 3-4 cells of those vegetation states. The status is "normal", if paddock is larger than 10 cells and consists of 3-4 cells of those vegetation states, or paddock is smaller or equal to 10 cells and consists of 1-2 cells of those vegetation states. The status is "thin", if those vegetation states disappear in the paddock. Herd size and cattle status were used to update newborn. If herd size is 5-14 herds, fat/normal, and thin cattle will produce 3 and 2 calves, respectively. If herd size is 15-25 herds, fat/normal, and thin cattle will produce 4 and 3 calves, respectively. If herd size is larger than 25 herds, fat/normal, and thin cattle will produce 8 and 5 calves, respectively. Criteria for numbers of death and loss cattle: random values from 0-4 were used. Herders who own cattle more than 25 heads have higher risk of death and loss. All criteria for calculation can be adjusted if players request.

There were 2 main phases to implement this model with human players. First, the key features, vegetation states and state transition diagram, were preliminary tested with small group of herders and NKU foresters to sensitize and allow them to validate the vegetation state transition proposed by researchers. Second, the model was implemented through a field workshop with larger groups of players. Four scenarios were explored with herders and foresters. The initialization and time horizon were different in each scenario depended on the available time. Scenario 1 (herders manage cattle without reforestation plots in landscape), 2 groups of herders were initialized with the same numbers. Six herders were separated into 2 groups based on the relative clan before playing the game. Scenario 2 (herders manage cattle in the landscape with reforestation plots of different ages), the different age of reforestation plots (2, 3, 5, 10, 20, and 25 years old) were initialized by researchers. The numbers of herders were same than scenario 1. Scenario 3 (reforestation without cattle grazing in the landscape), the 0 year old (new reforestation) plots were initiated in different zone in landscape. Scenario 4 (herders and foresters manage a common landscape), the different age of reforestation plots (0, 2, 5, and 10 years old) proposed by foresters were initialized. For herders, 2 groups were initialized with the same numbers (4 herders per group).

Sensitizing exercises on vegetation dynamics

Before to convene a field workshop bringing them together, sensitizing activities were held in separate groups with the herders and the foresters in order for them to better understand the research team proposition of ComMod activities. The main exercise consisted in the manipulation of pictograms representing different types of vegetation state to display vegetation state transitions and to explain them. It was also an initiation to collaborating modeling and sharing of perceptions and knowledge with other participants. Nine pictograms representing as many common kinds of vegetative cover in the area were introduced by the research team. They were rapidly recognized by the participants, who also easily displayed their relationships in transition sequences. But, because of differences in personal experiences, the opinions differed about the duration (in years) of several phases in vegetation successions. The group of NKU foresters also proposed to add a new type of vegetative cover called '*Chromolaena and imperata fallow'* in their vegetation state transition diagram. At the end of these separate group activities, two vegetation state transition diagrams were obtained from foresters and herders, respectively. Researchers finalized them in the lab. and used them to improve the representation of agro-ecological dynamics in the prototype ABM.

Participatory gaming and simulation field workshop

Three types of farmers (B, C and D) and NKU foresters were invited to take part because the objective of the workshop focused on the interactions between cattle rearing and reforestation.

<u>First day sessions with herders only</u>

In the morning session of day 1 held with two groups of herders at the village school, already trained players assisted newcomers to understand the vegetation pictograms and use them to build successions of vegetation states leading to forest recovery. The duration of each step was discussed as well as the effects of cattle grazing pressure on vegetation dynamics. Because of their different experiences in cattle rearing (different herd size, management techniques, and location of grazing land), the two groups produced different outputs regarding the duration of steps in vegetation transitions. They were also different from the one programmed in the prototype ABM based on the information obtained from the pre-workshop sensitizing exercises. In a second round of discussion, the herders were asked to discuss these differences and to agree on a common vegetation state transition diagram among them. Then, the researchers made the necessary modifications of parameters in the prototype ABM to adjust it to the latest proposition from the herders and the computer model could be used to update vegetation states depending on players' decisions in the afternoon session.

In the first half of the afternoon (session D1-A), the two groups of herders were asked to simulate a first scenario in which they had to manage cattle grazing in the absence of reforestation plots in the landscape. Most of the herders understood how the gaming and simulation exercise worked after playing a first round. But several herders who never received any formal education needed explanations in Hmong language from others. The dynamics of the landscapes managed by the two groups over four successive years are shown in Figure 9, while differences between the two groups regarding key monitoring indicators such as cattle population and status are provided in figure 10. We observed that some herders decided to test the management of larger herds than their actual ones in the first years, especially in the left group. But in the second and third rounds of play, we found that the herders related the landscape dynamics with their herd size before making decisions on location of grazing. Some of them decided to enlarge their paddocks to increase the volume of forage available to the animals, or decided to pool their individual herds into a small group of 2-3 owners with the objective of improving cattle fattening. A player decided to open a new plot to plant crops inside the forest area: “I sold some cattle last year and this year I have to grow crops for more income generation. But the land was occupied by other players so I needed to convert forest cells in my paddock.” But in this session there were no forester in the room to object to this type of land use decision. New information on social interactions and decisions making, that is impossible to gather during individual interviews, was obtained during this session through the observation of players’ mode of communication, behavior, negotiation on sharing grazing land, strategies to locate paddock, reasons to pool cattle in a single herd or not.

During a short plenary discussion, representatives of each group were invited to explain the individual and group strategies selected to manage cattle under this first scenario and to interpret their effects on the landscape features. They provided rapid explanations, without hesitation, and demonstrated their understanding of the gaming features and rules, and of the simulated dynamics. In particular, they were at ease with the use of pictograms to depict landscape dynamics and it was not difficult for them to relate them to real vegetation cover. As already observed by previous ComMod users in this region (Barnaud *et al.* 2007), they displayed strong relations between their decisions and behavior in the game and in actual circumstances. To them “the game is not difficult to understand and to follow because it is like what they do in reality. The game is fun but we think seriously how to manage the land. The game is an opportunity to discuss and share experience on cattle rearing and cropping activities.”

In the second half of the afternoon session, a second scenario was introduced in which reforestation plots of different ages were introduced in landscape in order for the herders to be preparing themselves to the gaming and simulation exercise planned with foresters the following day. But due to time constraints, as expected, only one round could be played in which both groups of players decided to locate their herds in every reforestation plots. The reason they offered was: “we have been rearing cattle in this area before foresters arrived. So, whether there are reforestation plots or not, we have the right to let our cattle graze everywhere.”

At the end of this first day, the importance of cattle rearing in this village and the herders’ wish to continue this activity were confirmed. But to be able to do so, the need to negotiate access to grazing land with foresters and other government agencies to mitigate the current land use conflict was also very obvious.

<u>Second day sessions with herders and NKU foresters</u>

The morning session started with presentations of the results of the previous day first scenario simulation (S1-A[2]) by representatives from each group of herders. This was to introduce the gaming and simulation tools, their features, rules, and the outcomes of a session to the foresters. It was also a way for them to learn more about herders’ perceptions of the issue at stake.

Thereafter, a new scenario “reforestation without cattle grazing in the landscape” (S3) was introduced and simulated with the agent-based model to let foresters learn about how a computer simulation works. At the same time, they could observe changes in vegetation dynamics in the absence of any cattle rearing activity. Following these two activities, the foresters were ready to participate in a full gaming and simulation session with the herders.

[2] S1-A was selected for presentation because we needed to observe herders’ behavior with and without foresters participating in the simulation.

It took place in the afternoon and was based on a fourth scenario “herders and foresters manage a common landscape” (S4). The dynamics of the landscapes managed by two groups of herders and the foresters establishing their reforestation plots over four successive years are shown in Figure 11, while differences between the two groups regarding key monitoring indicators such as vegetation cover and cattle population are provided in figure 12. The foresters started by selecting cells for reforestation, but requested to have different ages for their tree plantations in the landscape (0 for a new plot, and 2, 5, and 10 year old plots). They related the age of the reforestation stand with vegetation types (e.g. a 10 year old tree plot looked like *“Dense forest”*). Their new tree plantations were located next to the youngest ones because “we did like this in reality” to gradually expand the forest cover said foresters. They also announced that they would allow herders to let their herds graze in reforestation plots that are at least 5 year old and the herders accepted this rule. Later on, when the foresters, in fact the head of their group, faced difficulties in finding suitable cells to establish a new reforestation plot, they walked to the herders tables to negotiate access to a parcel of land for reforestation. This confirmed that foresters had well-understood the gaming features and rules.

The left group of herders used this simulation exercise to present their idea about using a small number of cattle for forest regeneration. They pooled their 40 heads of cattle together and started grazing in the upper part of the landscape, next to the forest area. After 3 years, they moved their herd to the lower part of the landscape where abundant grassy cells were available (figure 11). The right group of herders decided to raise a large herd (120 heads, see bottom part of figure 12). They managed their herds individually in the first two years, but they decided to pool them in the 3rd year when facing a lack of productive grazing land. As a result, the duration of the steps toward forest cover in the part of the landscape managed by this group was shorter than in the other one. This different forest regeneration in 2groups was related to the code programmed in ABM. This confirmed that herders understand well the forest regeneration and how computer simulation work, so they can apply their strategies in the gaming session.

Compared with the simulation of S2 in day 1, the groups of herders did not act in similar ways. In this scenario, they accepted the foresters’ rule and declared that they wanted to negotiate with them by showing that villagers could also accept and follow agreed upon rules.

In the final plenary discussion that took place after the simulation, the herders explained with much confidence the positive effects of cattle grazing on forest regeneration in front of the foresters. But they also made the point that they do not know what the herders will do if the whole area becomes gradually covered by dense forest. The results from this second day of gaming and simulation activities showed that they were efficient in facilitating the communication and sharing of perceptions between foresters and herders.

Each type of player also suggested to invite new participants to take part in the gaming and simulation process. NKU foresters thought that the head of NNP should participate because of his official authority over the park area, while the herders requested the presence of representatives of the District Office and Livestock Development at the District level because they still did not trust the NKU foresters to really help them to achieve their goal. Moreover, herders also want to test new cattle raising techniques such as paddock rotation and artificial pasture establishment using Ruzi grass (*Brachiaria ruziziensis*).

Because only a few herders participated in this field workshop, its main results were presented by the lead researcher and three herders-players during the following village meeting in front of about 100 villagers. The poster used was permanently displayed at the village healthcare center where one former player is working and is able to present the gaming and simulation workshop activities to interested visiting villagers. A similar document was also given to SKP officials and a meeting organized with Livestock Development officials at the District level. Both organizations seemed to be interested to participate in the subsequent ComMod activities.

Discussion

What did researchers learn during the collaborative modeling process?

This first sequence of ComMod activities in Doi Tiew village provides an opportunity to assess this collaborative modeling approach in the case of the co-construction of a tool representing dynamically the interactions between vegetation cover and cattle rearing in land management.

Strengths

There was much evolution of the tools used, from simple to more complex ones, all used interactively with local stakeholders to validate and enrich the researchers understanding of the question being examined. The participatory gaming and simulation sessions were efficient to improve communication and knowledge exchange among the different types of stakeholders, the research team being one of them. Social interactions were very much improved during the gaming sessions and the following interviews carried out after the workshop. These more relaxed relations between villagers and researchers are useful for designing the next steps of the process that will deal with the exploration of new cattle management techniques, with a broader arena of interested stakeholders as requested by the herders.

The high flexibility of model use with stakeholders was found to be another strong point. By playing and exchanging their views, participants could express their needs and suggest improvement leading to gradual modifications and improvement of the modeling tool making it more acceptable to users. For example, in this case the proposed rate of animal loss in large herds, due to accidents, diseases, predators or lack of care, was considered as too low by the herders-players and was subsequently increased. This kind of co-construction process is useful to a build a shared representation of the system to be managed and leads to the use of the validated simulator to explore collective management scenarios proposed by stakeholders (Castella 2009). The flexibility of the approach is also found in its capacity to involve new participants (from the same or new types of stakeholders) as needed during the evolution of the process. The tools themselves must evolve depending on the selected propositions for next steps made by the stakeholders to serve theirs objectives and answer their interest and new questions (Barnaud *et al.* 2007) . All together, the multiple adaptations of the activities implemented along the proceedings tend to bring a feeling of joint ownership of the modeling process among the stakeholders.

Weaknesses

Nevertheless this kind of collaborative modeling process is time consuming and request the mobilization and engagement of a significant amount of human resources equipped with complementary skills in ecology, social and computer sciences for trans-disciplinary modeling of a complex system with local actors. The engagement of several types of stakeholders is also difficult to secure and cannot be guaranteed. This is another reason why highly adaptive tools and activities are required.

But some key tools like role-playing games allow the involvement of only a limited number of participants (usually 10 to 20) in intensive and fast-paced gaming and simulation workshops. Complementary activities are needed to disseminate their results and to out-scale such ComMod activities. This can be efficiently done by presenting replays of actual gaming sessions by the computer ABM.

In Thailand, like in other parts of the world, past use of computer models has been dominated by the objective of predicting future situations. Therefore, much care and clarification is needed when introducing the ComMod modeling and simulation approach in such a context. The process designer needs to state repetitively the main objective of improved dialogue, sharing of perceptions and knowledge for joint learning to avoid misunderstandings during the collective exploration of scenarios and the analysis of key selected ecological and social indicators. The risk that what seems to be the best scenario will be taken as “recommendations” for actual implementation on the farm is always around the corner.

Table 2 proposes an assessment of the strong and weak points of the various tools used in this first cycle of the Doi Tiew Commod process. The simple tools are time consuming and costly, while computer simulation is time efficiency but it need to make sure that participants can follow. The key justification for selection of tools should be based on the research objectives (Hare *et al.* 2003, Castella *et al.* 2005, Becu *et al.* 2008).

What did herders and foresters receive from the collaborative modeling process?

Joint learning about the current conflicting situation under study and other people situations occurred among herders during the management of cattle in groups by using gaming and simulation tools. Players had to interact, to adapt their own management practices and to joint in exploring future options. A suitable atmosphere was also created to support serious discussions on how to solve the problem. At the individual level, some players also started to think about how to manage cattle, especially grazing pressure, on their farms and improve its product quality by using knowledge acquired during the simulation exercises. Other players, more concerned by their ability to continue rearing cattle in the near future if forest cover keeps increasing, suggested to introduce *Brachiaria ruziziensis* artificial pastures in the system to intensify forage production and decrease the pressure on forest areas. Others even considered alternative agricultural or off-farm activities if cattle rearing could not be pursued.

Learning on how simulations operate during the computer-assisted gaming sessions was found to be fast with most of these players, even if many of them never used a computer before. They also found convenient to use the computer to indicate rapidly the next vegetation states for each cell of the virtual landscape as they understood and agreed with the state transition diagram used to accelerate this otherwise very time-consuming step of the game.

The non-threatening environment created by the gaming and simulation activities led to a significant improvement in interactions and communication between villagers and foresters. On one hand, the villagers appreciated the fact that foresters walked to their tables to discuss with them, although such behavior is very rare in reality. And on the other hand, the foresters liked to see the villagers coming to them to negotiate rules on cattle access to reforestation areas. Moreover, they were surprised by the positive of their request for two cells for reforestation because they initially thought that the villagers will reject it. They realized that the villagers were more awareness of the importance of forest role than previously thought.

Simulation and gaming to build trust between different interest groups

After the completion of the 2 day workshop, the herders saw more clearly the urgent need for them to better manage grazing land, while foresters said they wanted to help herders moving into that direction and were ready to provide them with a piece of land to experiment new cattle rearing practices. However, researchers found that the level of herders’ trust in the foresters was still low when they requested to involve a representative from the District office to participate as a mediator. Therefore, it was decided to move on by modifying the current ABM to accommodate the exploration of new cattle management techniques (rotations and artificial pastures) as proposed by players and to use this new simulation tool with both the former and new interested stakeholders for collective decision support.

Conclusion

The implementation of a ComMod process at this site demonstrated that complex ecological and social dynamics related to cattle grazing and forest regeneration in montane Northern Thailand could be modeled with stakeholders after simplifying the system by selecting only key interactions between resources and different users to be included in the shared representation.

This experiment also confirmed that such a model can be used by on-farm researchers to improve communication and to support co-learning among the stakeholders concerned by this land use conflict. Differences in formal education levels were not a serious obstacle to the use of the proposed tools and the expression of own opinions as the non-threatening gaming environment and the interactive and visual features of the simulation tools allowed to manage the lack of confidence in public speaking and the local language barriers.

It was found that features and rules of the simulation tools that seemed rather complex to outsiders were not difficult to understand and use by the highland farmers and first time players because they deal with their everyday farming life and resource management practices. When important relevant interactions between users and resources were included into the gaming tools, they could act on them by making decisions strongly linked to their real circumstances and actual ways of managing the land. Players also learned by observing each other behavior and discussed various topics such as management techniques and strategies.

The ComMod activities implemented so far allowed the exploration of interactions and decision making processes related to cattle grazing and forest regeneration in a dynamic, inclusive and very interactive way. The simulation results showed that human decisions regarding cattle management are an important driving factor of the system behavior at the landscape level. Beyond the current conflict of interests, they also provided local stakeholders with convincing illustrations of the importance of resource users' coordination mechanisms if a sustainable management of the complex agro-ecosystem has to be achieved.

But in the search for acceptable collective management strategies, more concerned stakeholders, such as NNP and District Livestock Development managers should be involved in the process and be able to propose alternative land management options to be simulated and collectively assessed. This seems feasible in the next sequence of the ComMod process as its flexible characteristic and adaptive tools would allow the integration of new stakeholders (both an increased number of them as well as new types) in the process to share their perceptions of the problem at stake and join in the co-construction of a final model to be used.

Toward such an end, a second participatory gaming and simulation workshop will be conducted to test land use scenarios based on new cattle management techniques (paddock rotation and *Bracharia ruziziensis* artificial pastures) as requested by stakeholders. The future field activities will also include a collaborative monitoring and evaluation of the effects of this ComMod process on stakeholders' communication and learning.

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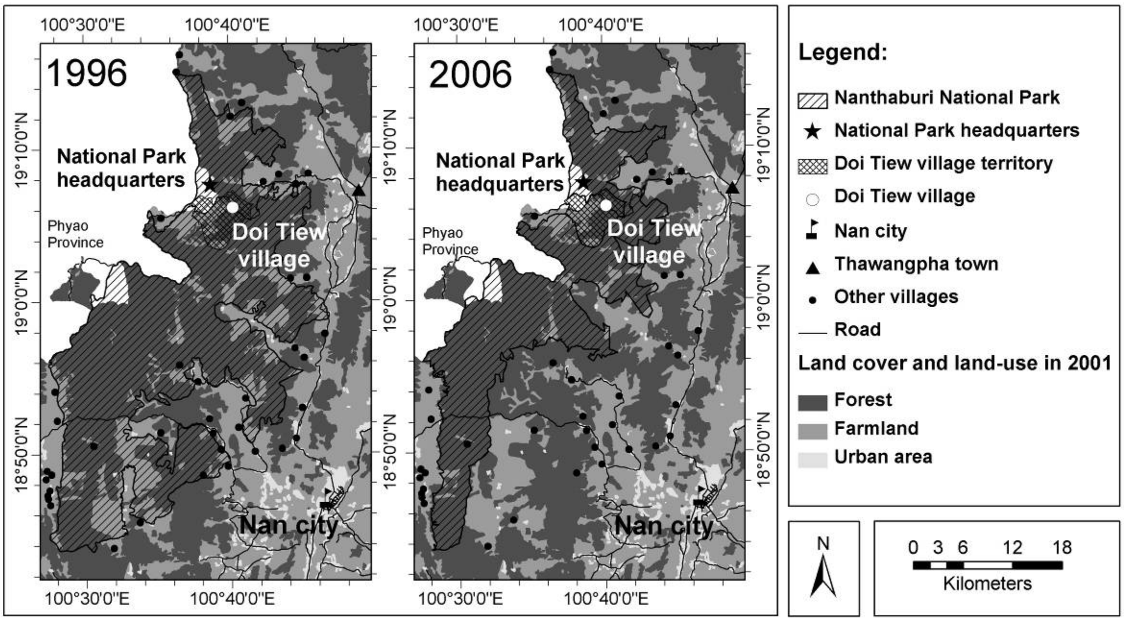


Figure 1. Change in Nantaburi national park boundaries between 1996 and 2006 and location of Doi Tiew village in Nan Province

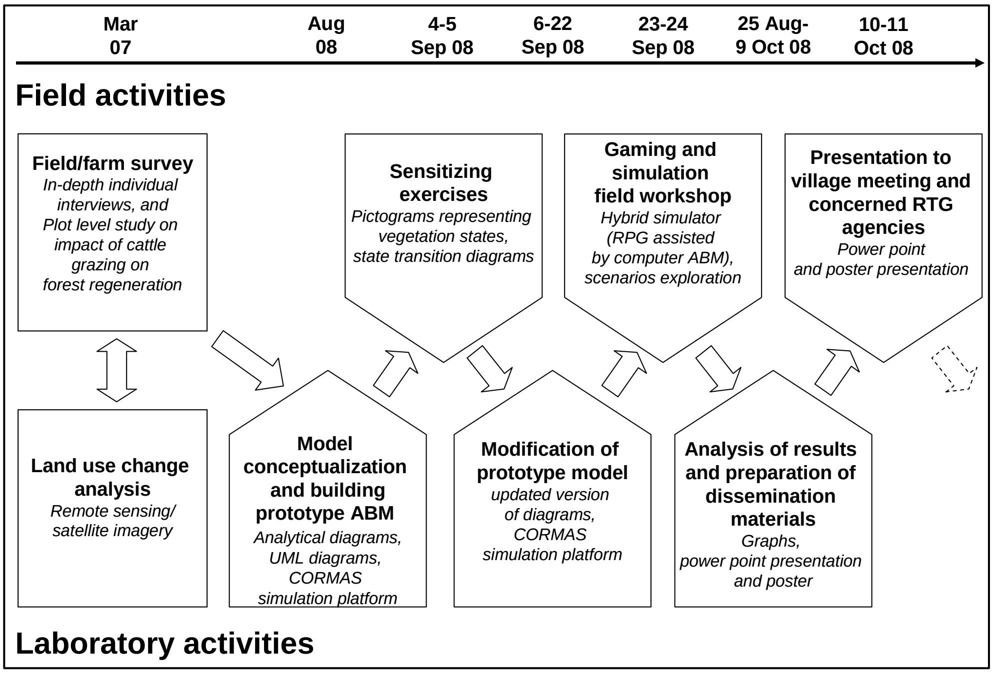
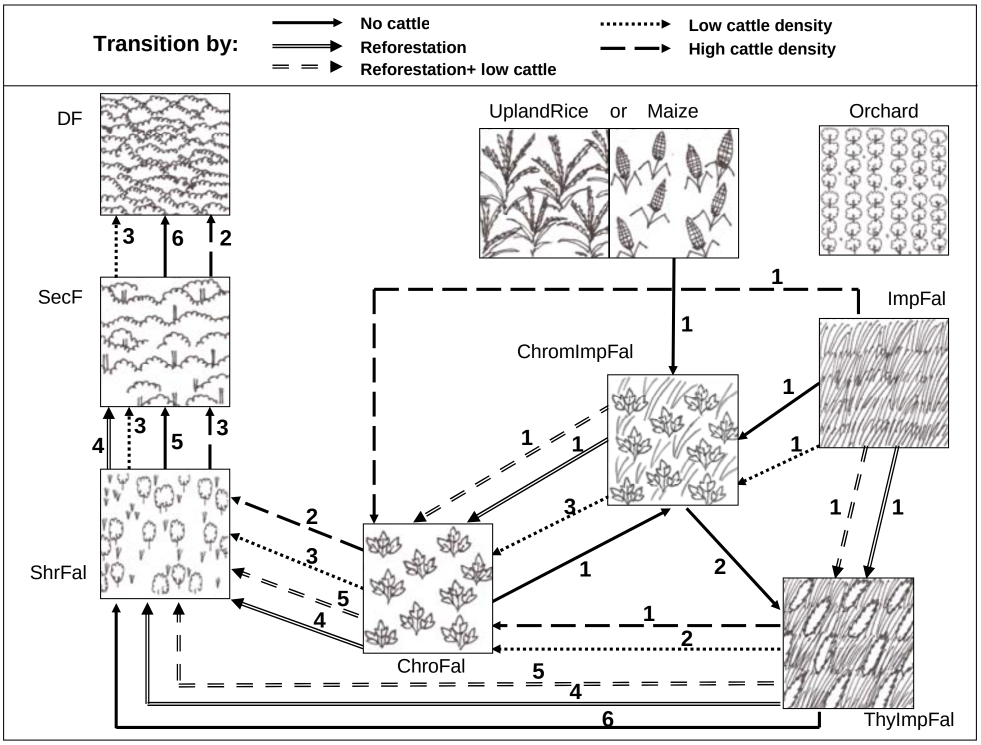
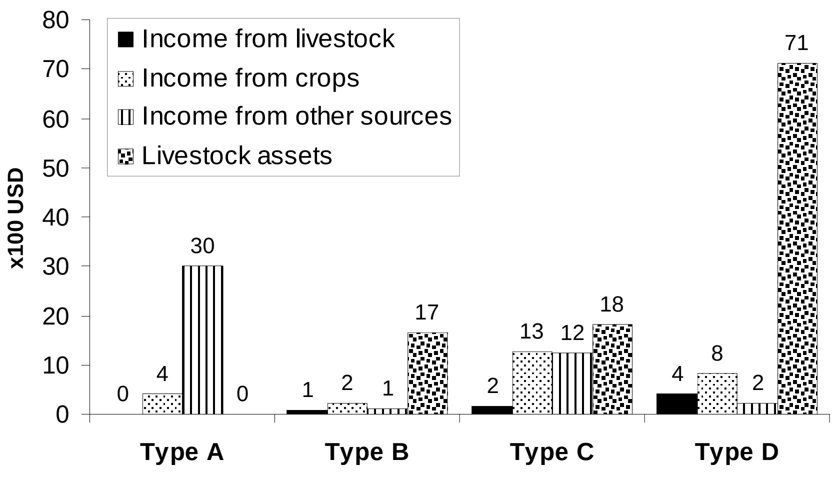


Figure 2. First cycle of the ComMod iterative and evolving process implemented in Doi Tiew village in Nan Province: Type of successive activities (in bold) and tools (in italic).



Note: DF = Dense forest, SecF = Secondary forest, ShrFal = Shrubby fallow, ChroFal = Chromolaena fallow, ThyImpFal = Thysanolaena and Imperata fallow, ChroImpFal = Chromolaena and Imperata fallow, ImpFal = Imperata fallow, and the numbers indicate the successive time (in year) for updating vegetation states. And in this extensive cattle raising system in reforestation area is low intensity

Figure 3. Vegetation state transition diagram used for programming the prototype of agent-based model



Note: other sources of income such as daily wage, salary wage, and petty commerce

Figure 4. Livestock assets and relative share of livestock products in annual income of 4 main types of farmers in Doi Tiew village, by own farm survey in 2007.

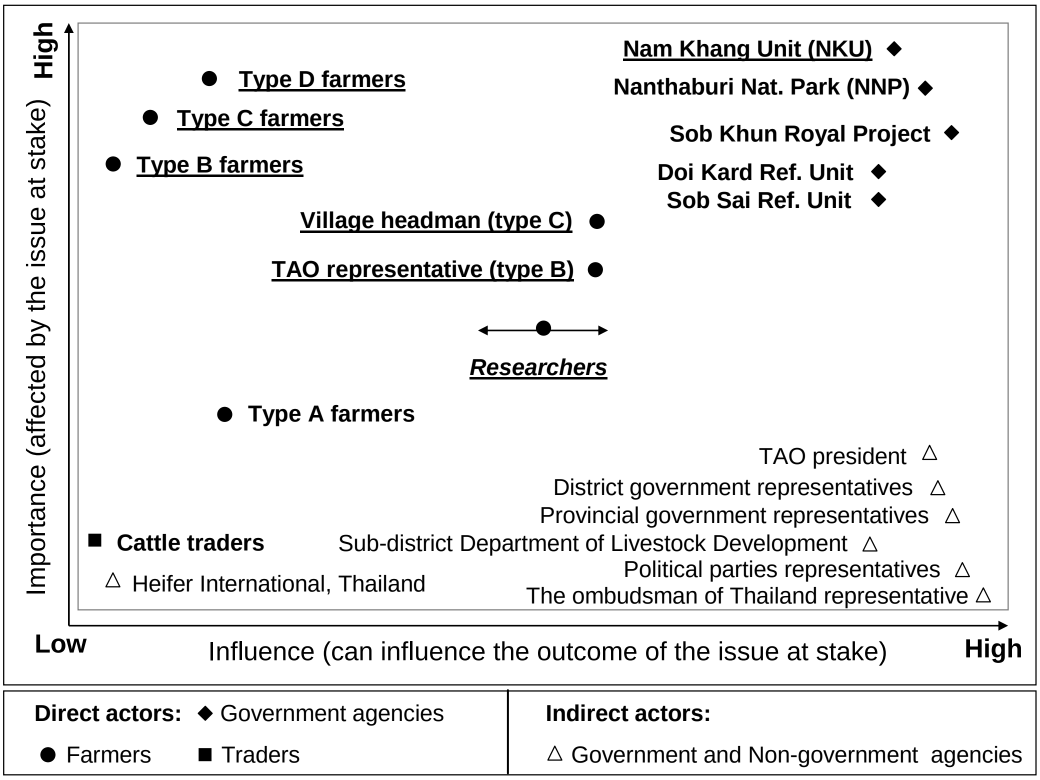


Figure 5. Relative importance of the issue for stakeholders and their Influence the outcome regarding the impact of cattle grazing on vegetation dynamics issue. The underline actors represent the stakeholders involving in the field gaming and simulation workshop.

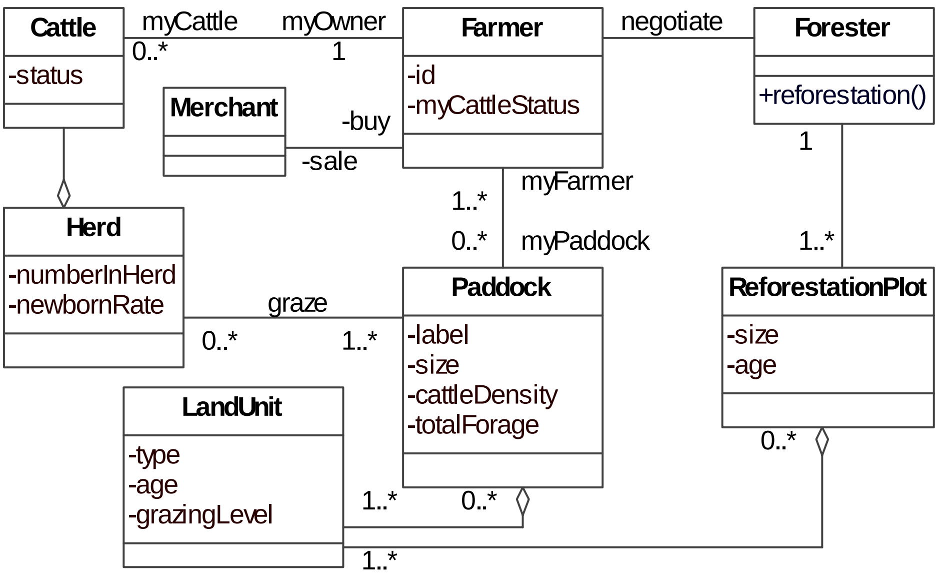


Figure 6. UML class diagram showing attributes and interactions between actors and resources (see more activities in the activity diagram in figure 8).

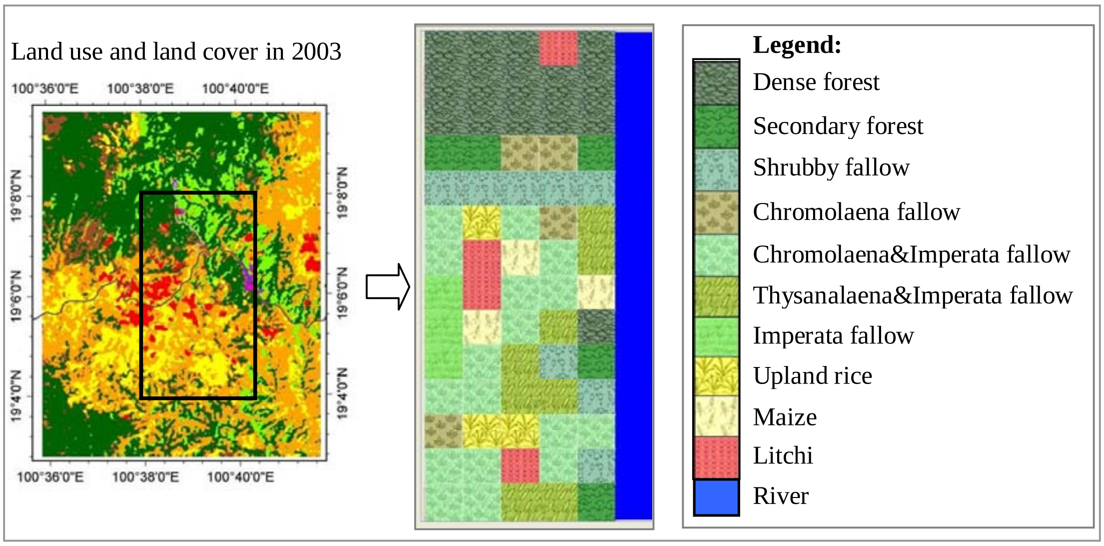


Figure 7. Simplification of land use in 2003 to spatial interface in CORMAS

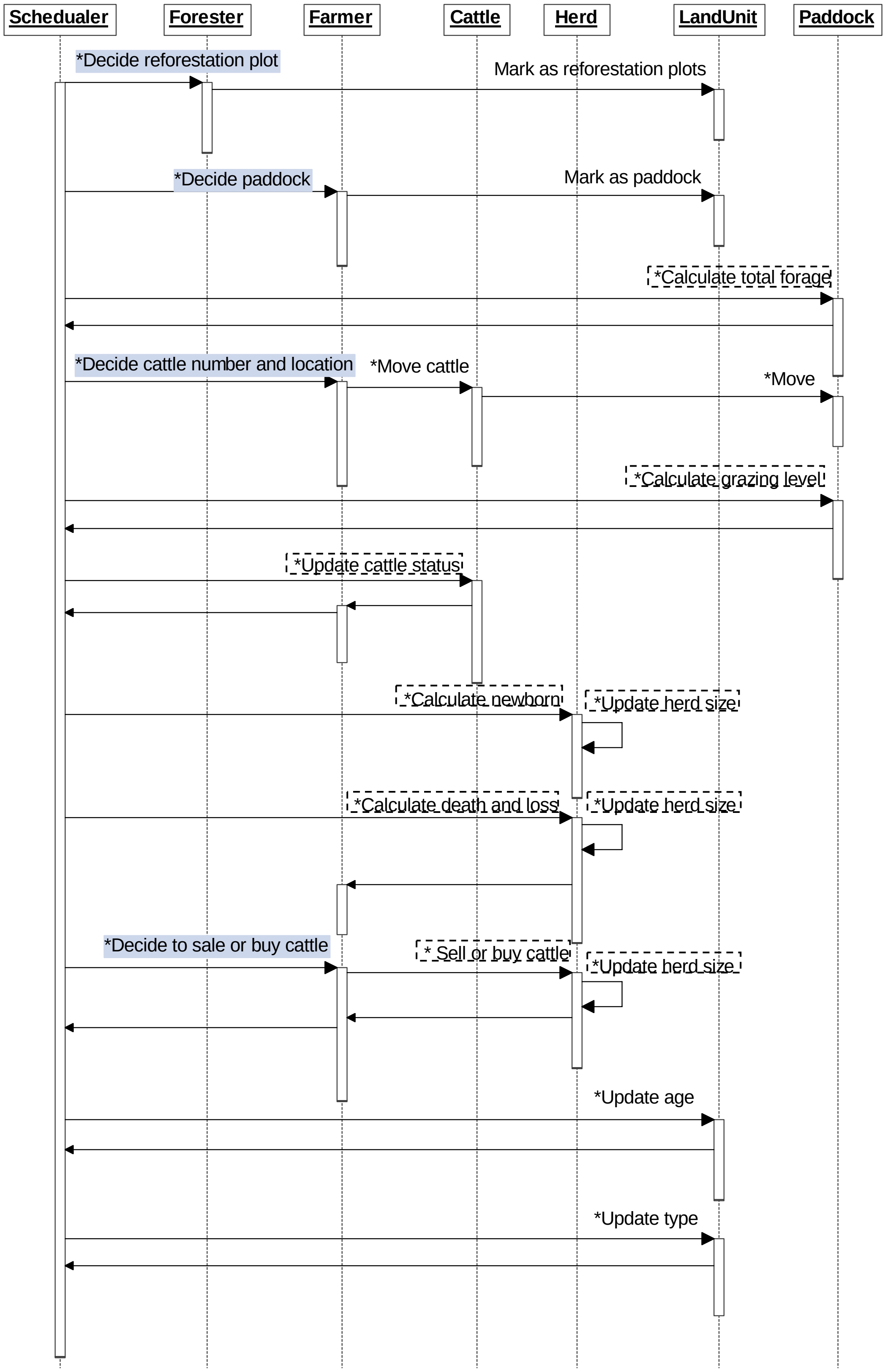
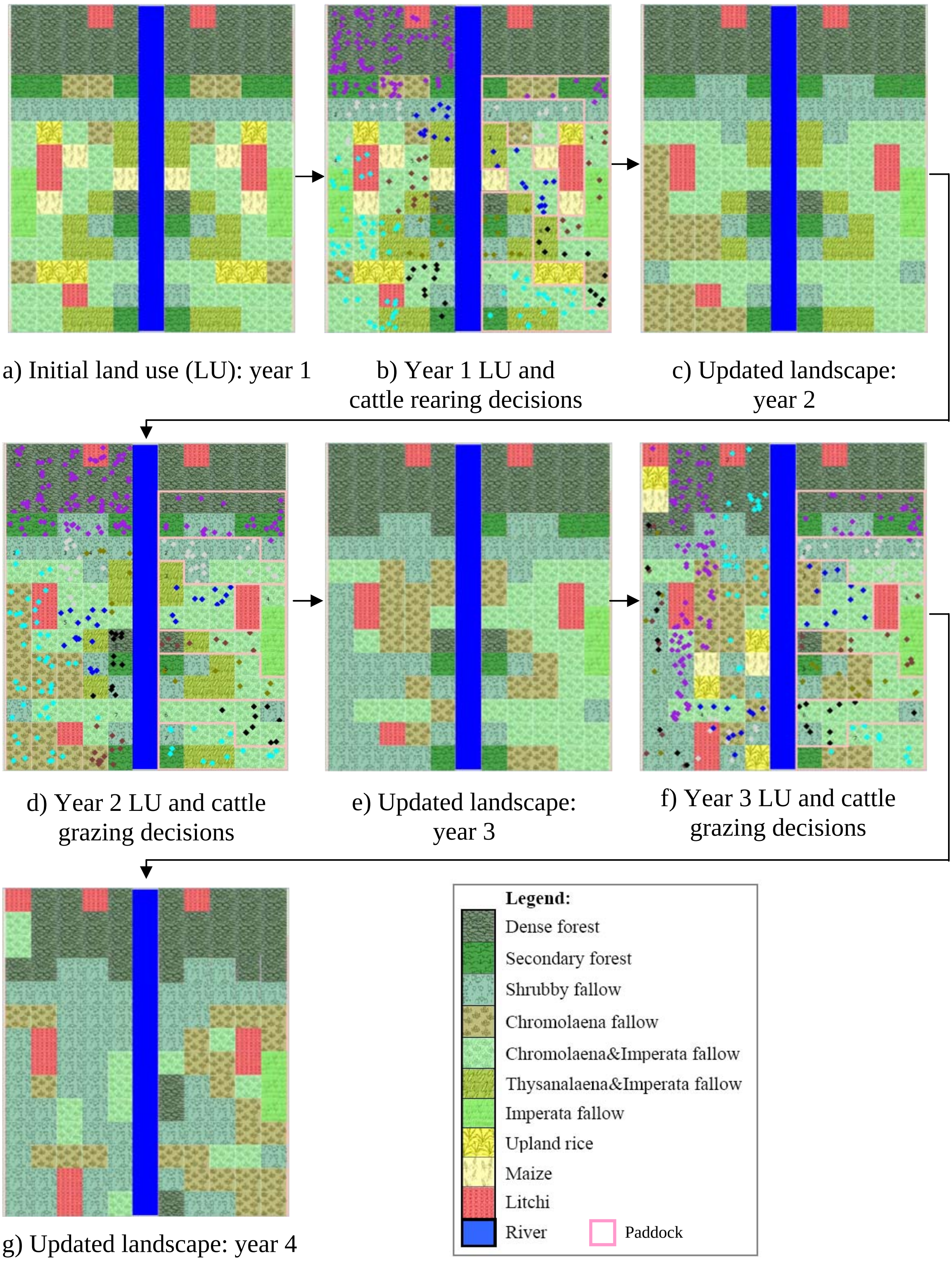
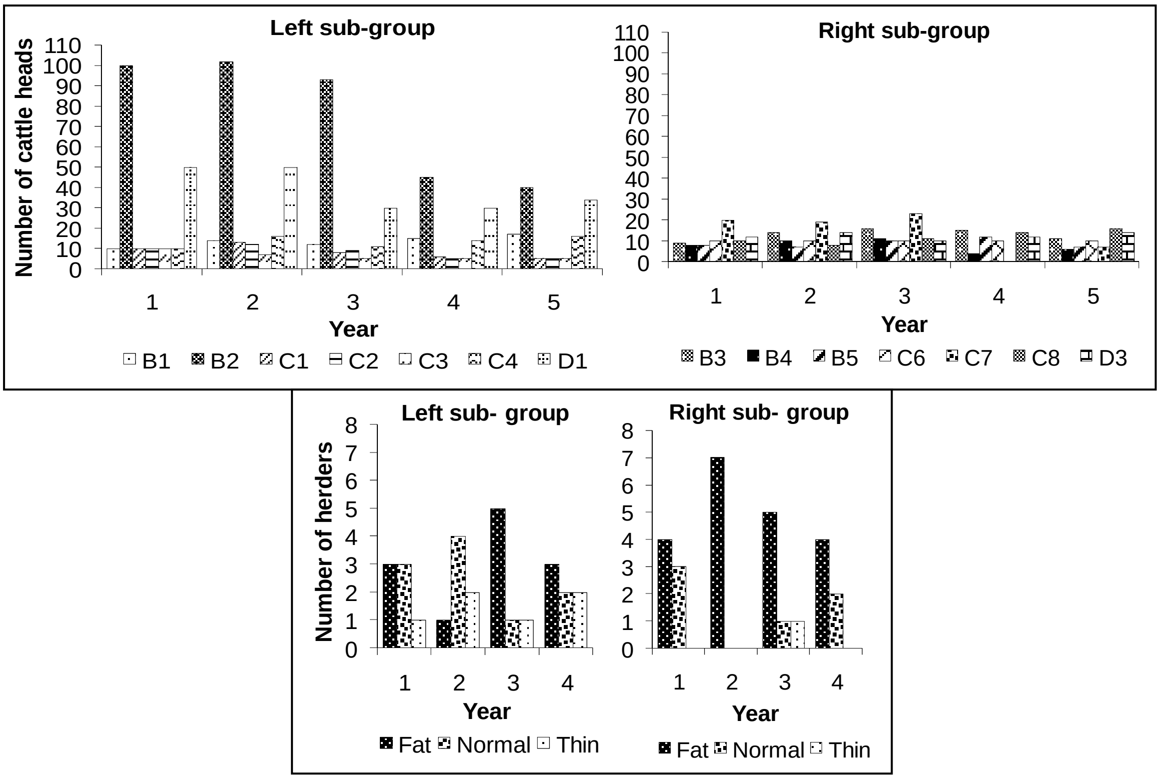


Figure 8. UML activity diagram showing the gaming and simulation process. Activities with gray background were decision making of real players. Activities with dash box were completed by research assistants, and other activities were computed in computer.



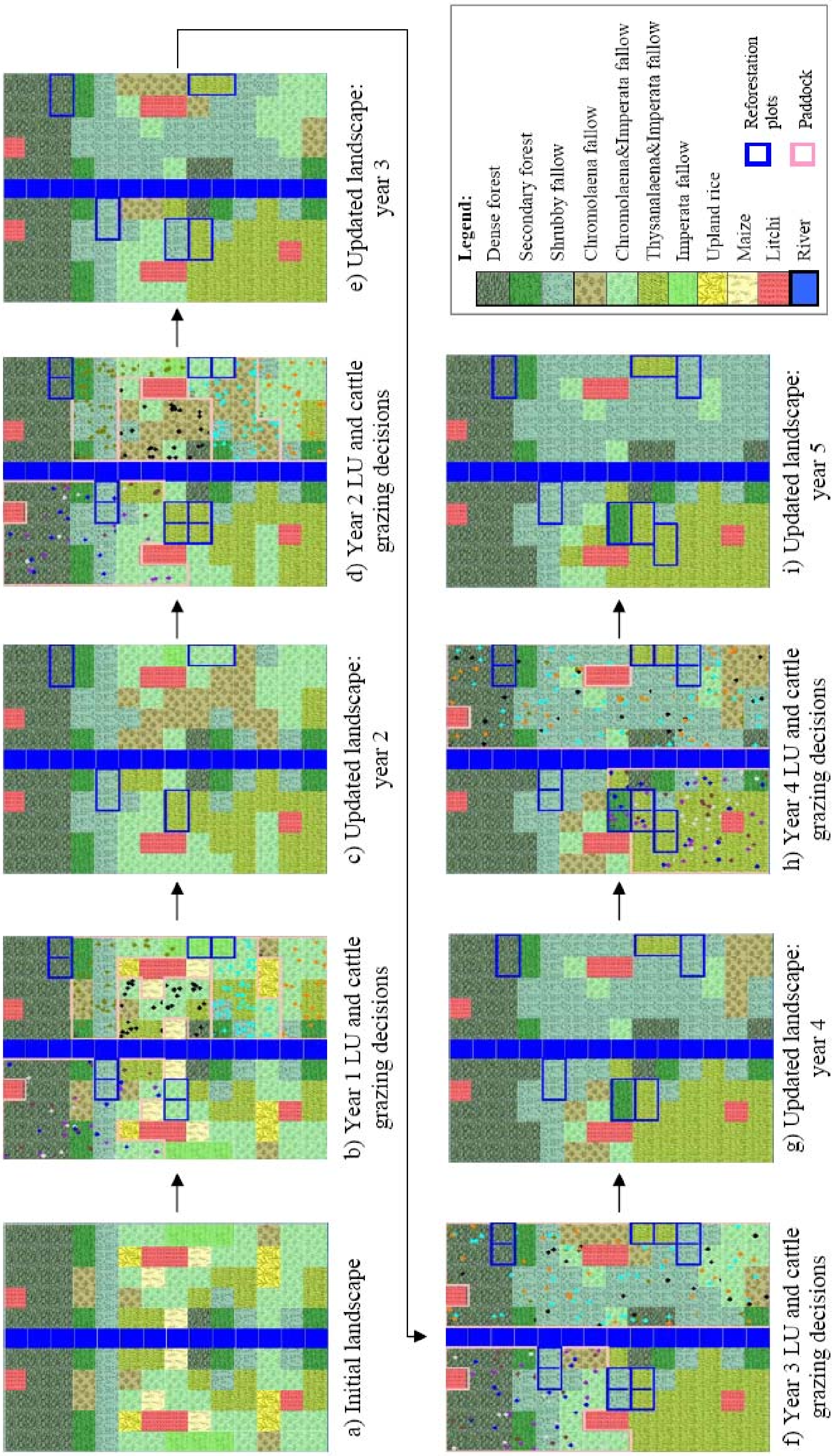
Note: dots of different colors denote cattle owned by different herders.

Figure 9. Landscape, paddocks, and cattle grazing dynamics for 2 groups of herders (left and right of river) with different management strategies during scenario 1 (herders manage cattle without reforestation plots in landscape)



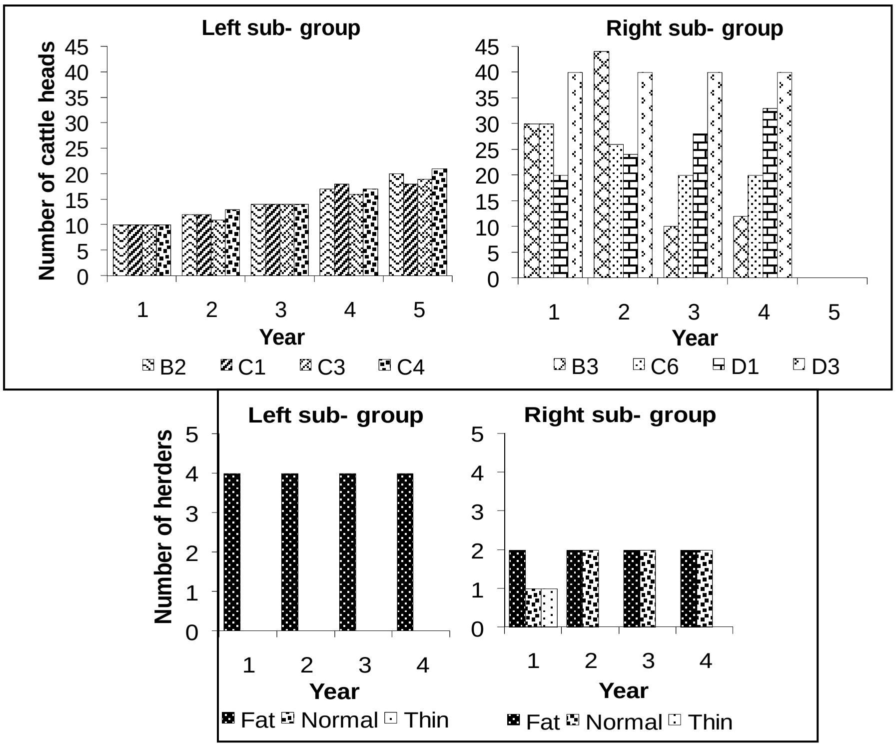
Note: Capital letter with number represent the code of herder players

Figure 10. Dynamics of cattle herd size and cattle status between 2 groups of herders with different management strategies during scenario 1 (herders manage cattle without reforestation plots in landscape)



Note: dots of different colors denote cattle owned by different herders.

Figure 11. Landscape, paddocks, and cattle grazing dynamics for 2 groups of herders (left and right of river) with different management strategies during scenario 2 (herders and foresters manage one landscape and negotiate with foresters to locate cattle in reforestation plots)



Note: Capital letter with number represent the code of herder players

Figure 12. Dynamics of cattle herd size and cattle status between 2 groups of herders with different management strategies during scenario 2 (herders and foresters manage one landscape and negotiate with foresters to locate cattle in reforestation plots)

List of tables

Table1. Details of sensitizing exercises and participatory gaming and simulation field workshop. (RPG = role-playing game, ABM= agent-based model).

Details	Sensitizing exercises	Gaming and simulation (G&S) workshop				Dissemination of G&S results
		Day 1-am	Day 1-pm	Day 2-am	Day 2-pm	
Objectives	- To test a simple gaming tool based on researcher 's understanding of vegetation dynamics influenced by cattle and fire - To better understand stakeholders' perceptions on vegetation dynamics - To sensitize a small group of stakeholders before their participation in a gaming workshop	- To introduce the gaming tool to newcomers - To explore with herders what needs to be modified in the researchers' representation of the system	- To investigate herders' decision-making process and interactions regarding cattle raising and forest regeneration - To prepare the herders to participate in a workshop with foresters by giving them more time to understand the game & simulation tool	- To present day 1-pm results and show to foresters how the computer - assisted RPG works - To demonstrate how the computer ABM works without entering players' decision on cattle raising and reforestation	- To investigate the foresters' and herders' decision-making process and interactions through a gaming & simu-lation session - To stimulate communication, collective learning and adaptive management between herders and foresters	- To disseminate workshop results to a larger group of non-players (villagers, Sob Khun Royal Project and District Livestock officers)
Types of partici-pants (numbers)	- NKU foresters (4) - Herders (5) - Researcher (1) - Assistant (1)	- Herders (13) - Researchers (4) - Assistants (7)	- Herders (14) - Researchers (4) - Assistants (7)	- NKU foresters (3) - Herders (8) - Researchers (3) - Assistants (7)		- Villagers (~100) - SKP officers (10)
Main tool used	- pictograms of vegetation states	- RPG using pictograms of vegetation states	- Computer-assisted RPG	- Computer simulation	- Computer-assisted RPG	- Power point presentation - Posters and workshop sum-mary document
Scenarios played and steps	- Vegetation dynamics affected by different factors (cattle density, fire, etc.). - Discuss and agree on vegetation state transitions with foresters and herders, separately.	- Herders indicate the next vegetation state based on given cattle number and paddock size	- S1: 2 groups of herders manage cattle without reforestation plots - S2: 2 groups of herders manage cattle with reforestation plots	- S3: demonstration of vegetation dynamics with reforestation plots and without cattle in landscape	- S4: herders and foresters manage a common landscape (negotiation is allowed)	- Formers players present results of Day 1-pm and Day 2-pm with researchers

Table2. Strengths and weaknesses of the tools used in the participatory gaming and simulation field workshop. (RPG = role-playing game).

Details	Tools used		
	Simple RPG using small pictograms	Computer-assisted RPG	Computer simulation
Strengths	- Easy to understand by villagers with no formal education - Useful for sensitizing players through gradual learning	- Easy to understand compared to computer simulation - Players can concentrate on their resource management decisions in the game, no need to update vegetation states by themselves - Players can discuss and learn by acting and observing other players' behavior	- Efficient time management - Several scenarios can be explored if players' strategies are known.
Weaknesses	- Costly in time to prepare - Time consuming when used, especially regular updating of vegetation states	- Costly in time to prepare - Time consuming when used, but less than when using the RPG only - Need several assistants during gaming sessions	- People with no formal education may not be able to follow or find it difficult to follow